

A Comparison of Observational Surf Forecasts on Oahu's North Shore



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Abstract

Knowing how to predict and estimate wave heights along Oahu's North Shore is critical for the safety of all beach patrons. Since 1968, the scale and format for describing wave heights for general public knowledge has been in constant dispute between national and local surf forecasting agencies. Today forecasts are given in two different wave scales, traditional Hawaii scale and trough-to-crest scale.(Face scale). The inconsistencies that arise when surf forecast media use two different wave scales has led to public confusion and the inability to correctly judge wave heights. From October 2006 to February 2007 surveys were collected at three different beaches on Oahu's North Shore: Alii Beach, Sunset Beach, and Pipeline. The survey compared the use of the two different wave height scales and the accuracy of the predicted wave height values given by surveyed beach patrons. Beach patrons were asked a series of short-answer questions concerning their prediction of the wave heights at the time surveyed, as well as preferred wave scale and surf forecast media. The mean standard deviation and mean coefficient of variation for the upper-end value of the predicted wave height range from each survey set was calculated. Overall low variability for both wave height scales was found. However, as the mean size of the wave height predictions increased, so did the standard deviation. Future research needs to be done to obtain accurate Face scale data and compare actual buoy measurements with observational wave height predictions.

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Introduction

Every year, between the months of October and March, some of the largest, most powerful waves in the world roll through Oahu's North Shore. People flock to the northern coast of Oahu from around the world to ride and watch these majestic powerhouses. The dangers that these waves pose however are immeasurable. Beach patrons who do not know how to predict wave heights, understand surf forecasts, or read the obvious (and hidden) signs of a dangerous sea are at risk when going to North Shore beaches during the winter months, even if they never set foot in the water. Understanding how to predict wave heights and interpret surf forecasts accurately is a necessity.

Since 1968, the City and County Lifeguards of Honolulu have made daily maximum surf height observations along the North Shore, between Haleiwa and Sunset (Figure 1), and these surf forecasts have been made available to the public through the Goddard-Caldwell (GC) digitized time series of visual surf observations. By 1981, other surf forecast media, both national and local, had also begun providing wave heights to the public. The City and County Lifeguards and many other media sources forecast observational wave heights in a format known as Hawaii scale. Hawaii scale estimates the wave height taken from an ocean-to-shore view, as if one was positioned behind the wave. When taken from the shore, this translates to one-half of the wave height seen the moment the wave front's greatest peak reaches its highest cresting. While this method of forecasting wave heights is known by most as the "traditional method," many inaccuracies and biases arise due to the short observational periods and the systematical underestimation of the wave height (Caldwell, 2005).

Before April 2001, the National Weather Service Forecast Office (WFO), part of the National Oceanic and Atmospheric Administration (NOAA), also issued surf forecasts using the Hawaii scale. However, since then the WFO has been reporting wave heights using a different

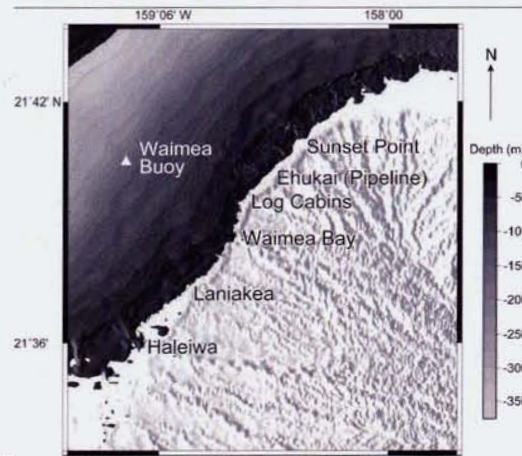


Figure 1. Map of the North Shore of Oahu from Haleiwa to Sunset Point, also depicting the location of the Waimea Buoy from the coast (Caldwell, 2005).

scale, a range of trough-to-crest heights. Trough-to-crest or face scale can be described as the “vertical distance between the crest and the preceding trough” when facing the front of the wave. While the WFO has been forecasting wave heights using the trough-to-crest scale, many other surf forecast media continue to report using the traditional Hawaii scale (Caldwell, 2004). The comparison chart in Figure 2 shows that a wave of 4 feet in Hawaii scale is the equivalent of 8 to 9 feet in Face scale. The values located in the middle of the chart are used to determine the relative wave height in comparison to a 6” tall man. These values were not recorded during the study.

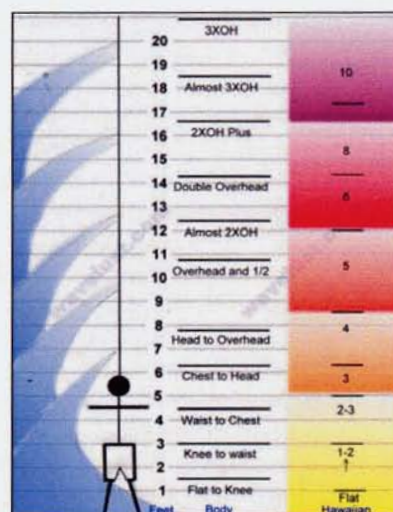


Figure 2. A conversion chart for determining equivalent wave heights for Hawaii scale, on the right, and Face scale, on the left (Wavelust, 2007)

The frequent use of two different wave forecasting scales and a vague understanding of wave predicting methodology have caused constant confusion when predicting wave heights. On the North Shore, beach patrons use both wave scales. Those who grew up and live in Hawaii or those who frequently visit most often use Hawaii scale. People visiting from the mainland United States or another country use the scale they are most familiar with from home. Then, there are the beach patrons that do not understand either scale and are unfamiliar with wave predictions in general. On any given day, a handful of beach patrons could predict several different wave heights for the same wave break within the same time frame. Who has the most correct wave height observation and which scale is used? How much do observations of wave heights vary among beach patrons who have viewed the same waves for at least one hour? Knowing whether there is a significant variance among beach patron wave predictions could arouse awareness among the wave forecasting community and provide the push needed to implement one standard wave predicting scale and an accompanying set of easy-to-use wave predicting rules.

Patrick Caldwell of the National Oceanographic Data Center (NODC) has been actively gathering and critiquing data related to the validity of visual surf observations in comparison with wave-measuring buoys on the North Shore. In his study, Caldwell plotted the relationship of documented wave observations from the GC database, recorded in Hawaii scale, against buoy 51001 breaker heights from 1981 to 2002. A high correlation was found, supporting the credibility of Hawaii scale surf observations (Caldwell, 2005). To date, no such study has been published comparing Face scale surf observations to wave-measuring buoy readings.

This experiment under the direction of Patrick Caldwell through the NODC provided a method for me to further study the validity of surf observations made using two different wave scales. I grew up and still live on the North Shore of Oahu. The North Shore waves have comprised a large part of my life. I have witnessed the dangers put forth by the massive waves

during the large winter swells. Lifeguards work tirelessly to prevent incidents and rescue beach patrons who are not familiar with North Shore waves. Perhaps if beach patrons clearly understood how to predict wave heights using a universal wave scale, a majority of lifeguard rescues could be avoided and many lives could be saved.

Methods and Materials

Between October 2006 and February 2007, 303 beach patrons were surveyed at the North Shore beaches of Alii, Sunset, and Pipeline (Figure 1). The three locations were chosen as survey sites based on the availability of surf forecasts for each. The surveys were conducted as sets, during which 10 or more different beach patrons were surveyed at one location in a single time frame. In total, 30 survey sets were completed. During the course of the study no beach patron was surveyed more than once, to avoid overlapping results. Any beach patron, whether a sunbather, swimmer, surfer, etc. who had been observing the waves for at least an hour was surveyed. All beach patrons were surveyed based on their willingness and consent to being questioned. No bias was given as to who was surveyed, unless they did not speak any English. Each survey set was completed between 30 minutes and one hour. All survey questions were from a standard questionnaire developed by Patrick Caldwell. Answers were initially written on a data sheet and then compiled into Microsoft Excel templates. To confirm survey data authenticity each patron was asked to write and sign their name above their information. For further study, personal information: address, phone number or email, was also recorded, with consent, so that patrons could be contacted at a later time if necessary.

On the preceding page is a list of the questions from the questionnaire.

Surf Observation Survey:

1. *Have you been here at least an hour? How long? (If no, then not suitable for the survey)*
2. *What are your observations of the surf size, as X to Y occasional Z (Z is the clean-up or sneaker set which may or may not occur, but if so, one set per hour roughly)*
3. *Is that Hawaii scale (HS) or face scale?*
4. *If HS is given, how many years have you used this scale?*
5. *Do you use indicators (which reefs are breaking, if channels are closing, strength of rips, beach run-up, etc) other than actual wave size when making your size judgement?*
6. *Where do you most often get your surf forecast?*
7. *Do you frequently look at buoy data, wave models, etc. to make your own prediction of surf/local winds?*

A supportive weather/ocean data sheet accompanied each survey set. For each completed survey set, wave height measurements from the Waimea buoy (Figure 1) and buoy 51001 (Figure 3), as well as wave forecasts from SNN and the National Weather Service were recorded onto the supportive data sheet. This data was recorded to provide additional analytical information.

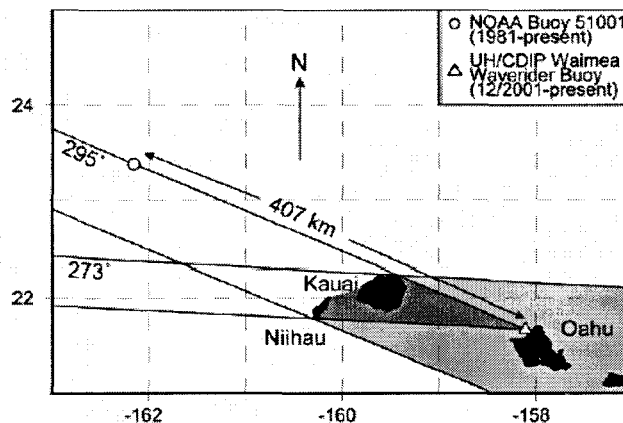


Figure 3. The location of buoy 51001 off of the Northwest coast of Kauai and in relation of the Waimea Buoy (Caldwell, 2005).

Survey data and supportive data from individual sets were compiled into Excel templates and then transferred to a main spreadsheet containing all sample data. Statistical analysis using Excel was performed using information from the main spreadsheet.

All materials were provided by Patrick Caldwell and myself including: copies of the questionnaire, data sheet, and supportive data sheet, as well as a vehicle, a clipboard, pens, towels, a computer with Microsoft Excel, a printer, and paper.

Timeline:

1. *Averaged 1 survey set every week between October 2006 and February 2007*
 - Each survey set took between 30 minutes and an hour to complete
 - Total time spent surveying equaled 30 hours
2. *Began compiling data in December using Microsoft Excel*
3. *Completed compiling data by March 1, 2007*
 - Total time spent compiling data was between 15 and 20 hours
4. *Progress reports submitted to MOP in late November, December, January, and February*
5. *Analysis began March 1, 2007 and was completed by April 25, 2007*
6. *Oral presentation at MOP Symposium given on April 14, 2007*
7. *Final report submitted to MOP on May 2, 2007*

Results

After four months of surveying, the total number surveyed equaled 303 people. As seen in Table 1, the number of predictions in Hawaii scale totaled 230, while the number of predictions in Face scale totaled 73. In terms of percentages, 76% of people surveyed reported wave heights in Hawaii scale and 24% reported wave heights in Face scale. The wave scale used five times or more in a survey set was used to calculate the mean wave height, standard deviation, and coefficient of variation for that survey set. The upper-end value of each predicted wave height range was used for the calculations. Hawaii scale was used five times or more for 28 survey sets, while Face scale was only used five times or more for seven survey sets. Hawaii scale and Face scale were used equally, five times each, for five survey sets. The mean standard deviation and the mean coefficient of variation was calculated using all survey set data to determine the total amount of variation for each wave scale (Table 1). The mean standard deviation denotes how many feet on average people skewed from the mean wave height

predicted during any given survey set. In Table 1, on average, people deviated 1.24 feet from the mean for Hawaii scale. For Face scale, people deviated 2.99 feet from the mean. The mean standard deviation for Face scale was over twice that of Hawaii scale. When the outliers, those predictions beyond one or two standard deviations, were removed from the data set, the corrected mean standard deviation decreased to 0.974 feet for Hawaii scale, while that for Face scale decreased to 1.97 feet.

The mean coefficient of variation, relative standard deviation, measures the percent of variation among the overall data for each wave scale (Table 1). The mean coefficient of variation for Hawaii scale was 23.3%, and 31.9% for Face scale. After the data was corrected, outliers removed, the mean coefficient of variation decreased for both wave scales. Hawaii scale had a corrected coefficient of variation of 19.7%, and Face scale had a coefficient of variation of 22.0%. More variation was seen within Face scale.

The percent of people surveyed who predicted wave heights beyond one standard deviation for Hawaii scale was 7.25%, while that for Face scale was 0.99% (Table 1). The percent of people surveyed who predicted wave heights beyond two standard deviations for both scales was 0.33%.

Table 1. Calculated mean standard deviation, mean coefficient of variation, and percent beyond one and two standard deviations for Hawaii scale and Face scale.

| Wave Scale | Number Surveyed | Mean Standard Deviation (feet) | Mean Coefficient of Variation (%) | % Beyond one Standard Deviation | % Beyond two Standard Deviations | Corrected Mean Standard Deviation (feet) | Corrected Mean Coefficient of Variation (%) |
|------------|-----------------|--------------------------------|-----------------------------------|---------------------------------|----------------------------------|--|---|
| Hawaii | 230 | 1.24115 | 23.27685 | 7.26 | 0.33 | 0.97364909 | 19.65942088 |
| Face | 73 | 2.99341 | 31.91414 | 0.99 | 0.33 | 1.9705503 | 22.00308 |

The regression plots comparing the variability in mean wave height predictions versus standard deviation, Figures 4 and 5, show positive trends. As the mean wave height prediction

increased so did the standard deviation for both wave scales. For Hawaii scale, 78% of the variability was explained by the mean wave height, while for Face scale, 56% of the variability was explained by the mean wave height as given by the R^2 value within each graph.

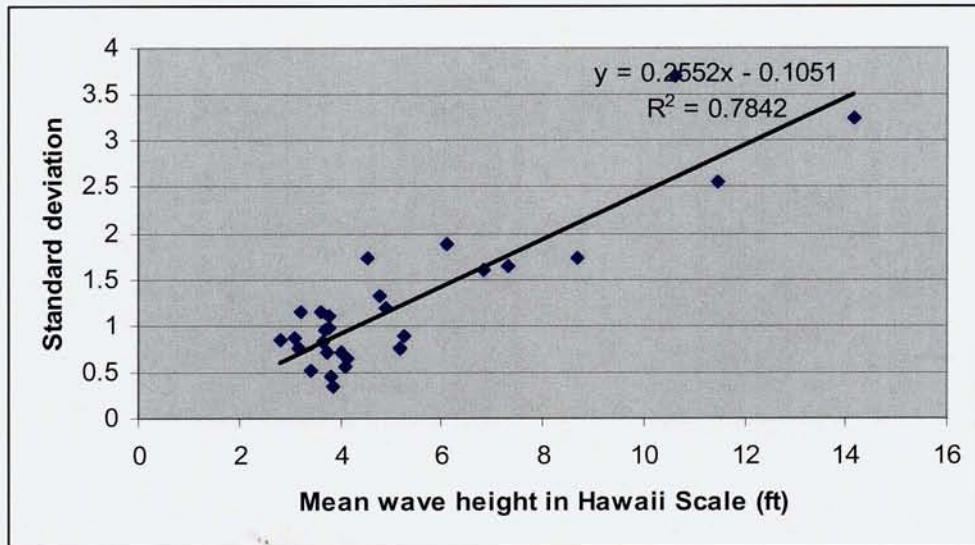


Figure 4. Regression plot of Hawaii scale data comparing the variability of mean wave height, in feet, with the standard deviation.

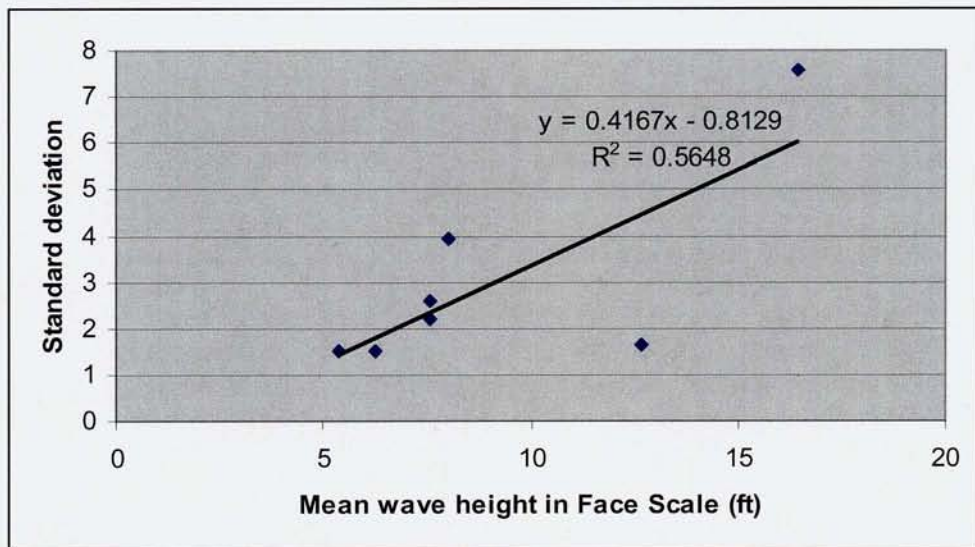


Figure 5. Regression plot of Face scale data comparing the variability of mean wave height, in feet, with the standard deviation.

The bar graph in Figure 6 shows the number of people surveyed who have been using Hawaii scale for a given range of years. Of the 230 people surveyed in Hawaii scale, 16.9% have been using Hawaii scale between 0 and 4 years and 54.8% surveyed have used Hawaii scale between 0 and 19 years. Only 4 people surveyed have been using Hawaii scale for over 50 years. No year range data for Face scale was collected.

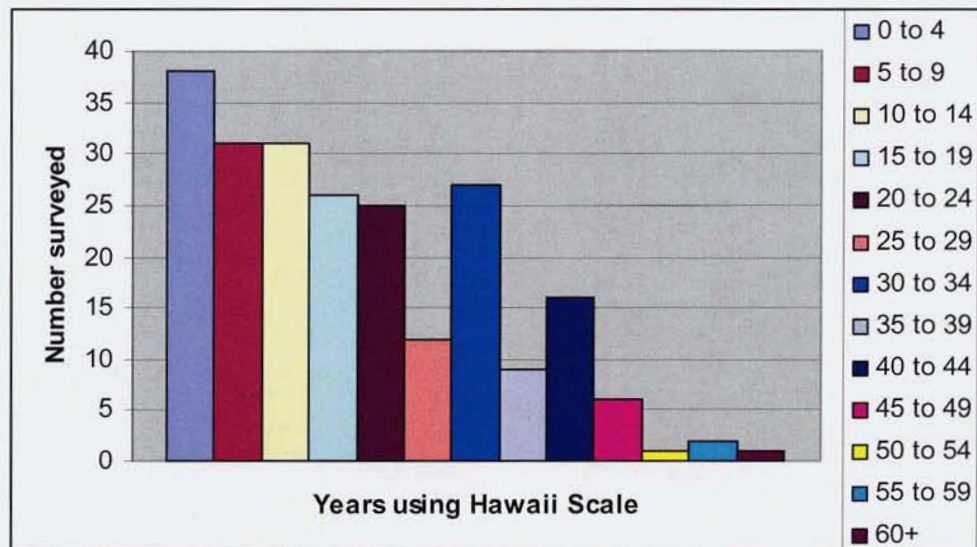


Figure 6. Bar graph depicting the number of people surveyed who have used Hawaii scale for a given range of years. Total surveyed that used Hawaii scale equaled 230.

The histogram of the standard deviation outliers for Hawaii scale, Figure 7a, shows that a majority of people surveyed who have been using Hawaii scale for 0 to 14 years tend to deviate from the mean wave height predictions. Out of 23 surveyed who were beyond one standard deviation, 70% have been using Hawaii scale between 0 and 19 years. Another noticeable spike in the data appears within the 30 to 34 year range, when 3 people out of 23 (13%) surveyed were beyond one standard deviation of the mean. All other year ranges recorded one or zero standard deviations. Figure 7b depicts the year ranges of those surveyed who use Hawaii scale and were within one standard deviation. Not enough data was available to construct bar graphs for those beyond two standard deviations.

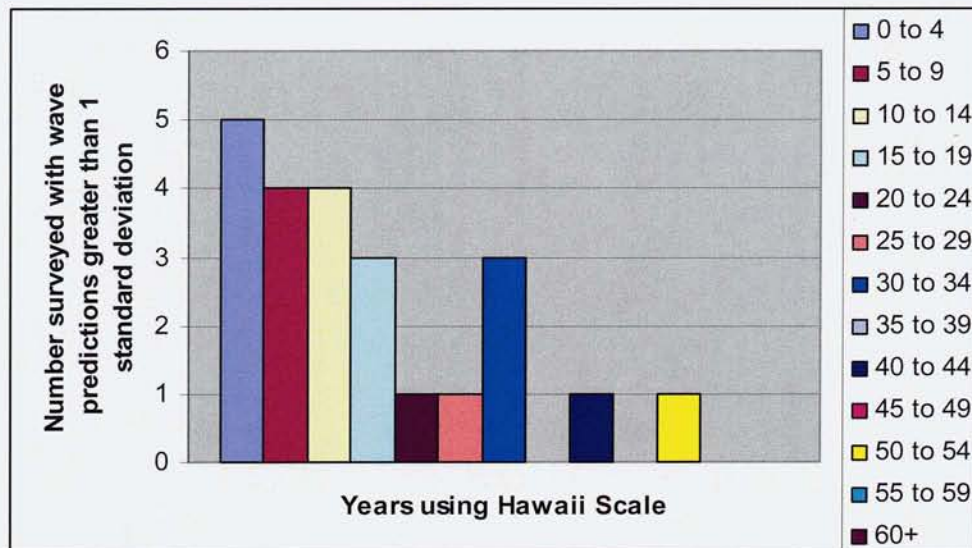


Figure 7a. Bar graph depicting the number of people that have used the Hawaii scale for a given range of years who predicted wave heights greater than one standard deviation from the mean for Hawaii scale. Total surveyed that were beyond one standard deviation for Hawaii scale equaled 23 of 230.

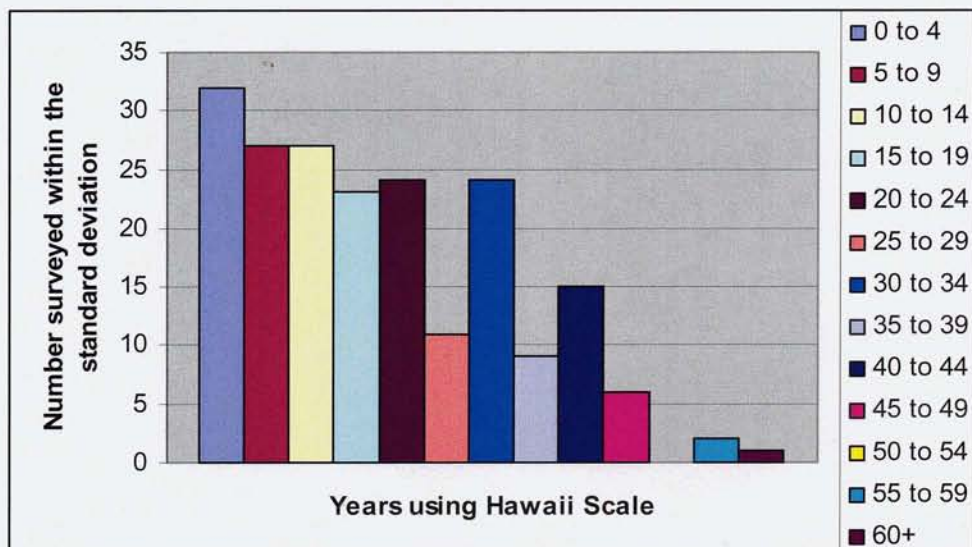


Figure 7b. Bar graph depicting the number of people that have used Hawaii scale for a given range of years who were within the standard deviation of the mean. Total surveyed within the standard deviation for Hawaii scale equaled 207 of 230.

Histograms depicting wave forecasting sources most often used are shown in Figures 8 and 9. Of the 357 responses relating to preferred wave forecasting source, 43% reported the internet as the preferred source. Only 1.4% of those surveyed use the newspaper as a wave forecasting source. For those who used the internet for wave forecasts, 98 people reported which

specific website they favored, Figure 9. The most popular internet websites included: Surf News Network with 38% of those surveyed and Surflife with 26% of those surveyed.

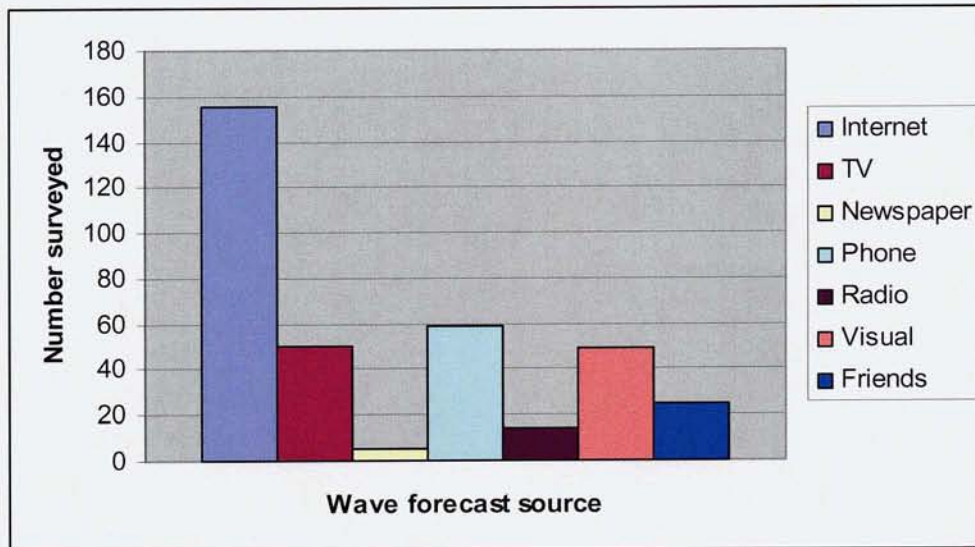


Figure 8. Bar graph depicting the number of people surveyed who reported using a given wave forecasting source. Number of responses equaled 357.

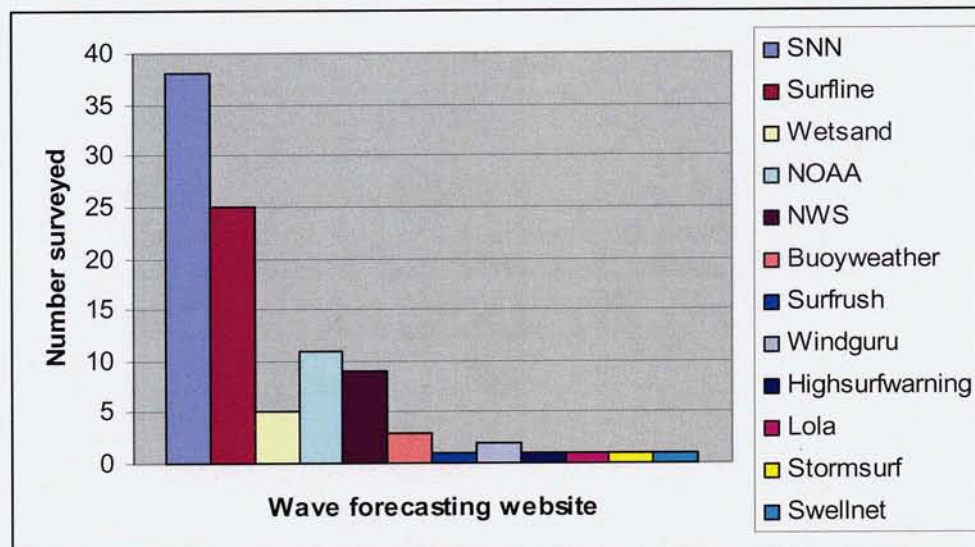


Figure 9. Bar graph depicting the number of people surveyed who reported using a specific website. Number of responses equaled 98.

Discussion

Of course everyone is going to have a different opinion as to how large the waves are at any given time on the beach. The real question is how much variation is there between beach patron predictions for both Hawaii scale and Face scale? I set out to answer this question. After surveying 303 beach patrons at the world renowned beaches of Alii Beach, Sunset Beach, and Pipeline, and conducting statistical tests using Microsoft Excel, I have come to the conclusion that little variation for observational predictions in Hawaii scale was seen on average. The mean standard deviation for Hawaii scale equaled 1.24 feet (Table 1). This value was not significantly high, since wave heights often fluctuate over short periods of time. The percentage of variability, coefficient of variation, for Hawaii scale was also relatively low at 23.3%. When the outliers of the data set for Hawaii scale were removed, the corrected mean standard deviation and coefficient of variation dropped to 0.943 feet and 19.7% respectively.

However, for Face scale the mean standard deviation and coefficient of deviation were larger than those for Hawaii scale. The mean standard deviation for Face scale equaled 2.99 feet, while the coefficient of variation equaled 31.9%. After the outliers were removed, the corrected mean standard deviation and coefficient of variation dropped to 1.97 feet and 22.0% respectively.

Although Face scale did have a higher level of variability it must be taken into account that a one foot wave in Hawaii scale is the equivalent of a two foot wave in Face scale. Therefore, the variation within and between both wave scales can be considered low and nearly equal to one another. A large margin of error arose for the Face scale data, since the sample size was much smaller than that for Hawaii scale. Overall, only seven standard deviation and coefficient of variation values were used to determine the mean values for Face scale. This was fewer compared to the 28 values used for Hawaii scale. For this reason, much of the Face scale data may not reflect everyday values.

The percentage of beach patrons who predicted beyond one or two standard deviations (Table 1) was very low for both scales and had only a marginal effect on the corrected mean values. For data concerning Hawaii scale, it was determined that 70% of beach patrons who predicted beyond one standard deviation had been using Hawaii scale anywhere between 0 and 19 years (Figure 7a). This seemed natural for beach patrons who had only been using Hawaii scale between 0 and 9 years; those with less experience often made inaccurate predictions. However, I did not expect to see so many outliers made by beach patrons that have used Hawaii scale for over 10 years. This could be attributed to length of time at the beach before the survey was conducted. The waves may have been larger at an earlier time of the day and those values may have been reported during the survey. Also, for all data, 54.8% of people surveyed had been using Hawaii scale between 0 and 19 years (Figure 6). More people sampled within that year range could have led to more frequent predictions beyond one standard deviation.

Low variability was seen on average, but the positive trends in the regression plots, Figures 4 and 5, shows that as the mean wave height predictions grew larger so did the standard deviation. Although beach patrons showed low variability in their wave predictions for both scales, as the height of the waves grew larger, people tended to skew away from the mean predicted wave height values. This trend was also seen by Patrick Caldwell during his study the observational wave heights in which the digitized wave heights of the GC time series collaborated with concurrent buoy readings; however a greater margin of error was seen as wave heights increased (2005).

Prior to the beginning of the study, Patrick Caldwell and I felt that a main reason for any variability would be due to media confusion. Many beach patrons who do not clearly understand the mechanisms involved in predicting wave heights may fall victim to the failure of different surf forecast media to report wave heights in the same scale. We felt that this would cause a large

amount of variability. However, the low variability seen overall and the overwhelming use of a wave forecasting media that readily provides wave heights in both scales has made me rethink my earlier conviction. Of five different wave forecasting media, the internet was preferred by 43% of people surveyed (Figure 8). The internet is the only forecasting source that consistently makes available websites offering wave height forecasts in both Hawaii and Face scale. Some of these websites include Surf News Network and Surflife. In Figure 9, 38% of the people who most often used the internet as a forecasting source preferred Surf News Network, while 26% preferred Surflife. This shows that many beach patrons are receiving information in both scales and are applying them appropriately to observational forecasting. Most of the variability probably arose from wave height observations made much earlier in the day (before the survey was taken), and from lack of experience.

For the future, more data should be gathered concerning Face scale predictions and the number of years used by beach patrons. This I recommend to anyone who wants to get a well rounded data set. Also, a comparison of observational wave forecasts by beach patrons against buoy data should be conducted, for a true understanding of how well beach patrons can predict actual wave heights. However, caution must be taken since buoy readings may not necessarily correlate with the actual size of the waves at certain beaches, due to shoaling and position on the coastline. Only further testing will truly determine the accuracy and consistency of observational wave height predictions. For now, people appear to understand enough to at least determine wave heights accurately on average.

Evaluation of Learning

Although a lot of work, surveying people was very exciting and worthwhile. I never knew that I could have so much fun discussing the ocean with so many different people. Sure going up and asking people to take my survey was a little nerve racking at first, but I grew comfortable with approaching beach patrons and asking them for their input. If people did not want to be part of my survey, I learned to just thank them and move on, instead of take their rejection personally.

While taking my surveys I met people from all over the world, who knew how to predict waves and who didn't. Almost everyone had very rational and interesting ideas concerning the main topics of my study. I learned more about the intricacies of my project through hearing of people's experiences and ideas than I did on my own doing internet and book research. By the time I had finished gathering all of my data my project was focused solely on what I had gathered from people at the beach. None of the other digital information that I had compiled was included in my final report.

If I learned anything at all, I learned that working independently to gain knowledge requires a lot of dedication and attention to detail. Getting down to the beach to take surveys as often as possible tested my patience and dedication. In the end, I completed all of my responsibilities, without any lack of dedication towards obtaining my main goal. Making sure I was prepared and paying attention to detail became a big deal. Before I took any surveys, I thought I had planned everything out and that I knew exactly what I was going to study; however, going out and surveying people on my own opened my eyes to many possibilities for which I could focus my study. Staying on track, with a single goal in mind was difficult because everyday new ideas would enter my head. In the end, I learned to focus on one main idea,

although I had gathered enough data to write two complete two experiments. Taking surveys tested my organizational, speaking, people, and time management skills, but I proved to myself that with time and dedication I could accomplish something great.

First and foremost I want to thank Jeff Kuwabara for suggesting that I get in touch with Patrick Caldwell in the first place. I have always enjoyed the North Shore waves and getting the chance to study them was a dream come true thanks to Patrick Caldwell, my mentor. Without his guidance and knowledge, I would not have known where to begin and end. I acknowledge Sherwood Maynard and Jeff Kuwabara for correcting and accepting my proposal. Also I would like to thank James Hardy for helping me to complete surveys. Finally, thank you to Andrew Taylor for helping me to sort out some data analysis problems.

This study went better than I had imagined that it would. I gained so much in just over six months, including: public speaking skills, data analysis and problem solving skills, personal connections in the marine field, and the John P. Craven award for “Child of the sea” at the MOP Symposium. In terms of data, I gathered what I thought I needed at the time, but now I know that I needed to balance my data by gathering data concerning the number of years patrons had been using Face scale. I wish that I had more predictions in Face scale and as of right now I don’t know how I could have gathered more. I suggest that anyone who wants to compare the use of the two different wave scales on Oahu’s North Shore find another couple of people to help take surveys, and then surveying more patrons would be easier. Perhaps this would allow for more Face scale predictions to be gathered.

Once again, completing this study was a worthwhile, lifetime achievement and I thank everyone who made it a reality.

References

- Caldwell, P.C. 2004. Translation from Hawaii Scale to Trough-to-Crest Heights. 8th International Workshop of Wave Forecasting and Hindcasting [Online]. Available: <http://ilikai.soest.hawaii.edu/HILO/poster.pdf> [2007, May 1].
- Caldwell, P.C. 2005. Validity of North Shore, Oahu, Hawaiian Islands Surf Observatoins. Journal of Coastal Research. 21:1127-1138. [Online] Available: <http://micro189.lib3.hawaii.edu:2028/perlserv/?request=get-document&issn=1551-5036&volume=021&issue=06&page=1127> [2007, May 1].
- Wavelust.com. 2007. 808surfer.com [Online]. Available: <http://www.wavelust.com> [2007, May 1].